1907MNRAS..68...19L

can be no reasonable doubt that the extinction of the Sun, recorded as an omen, was likewise witnessed from Babylon itself.

(2) The date of the phenomenon is given as Sivan 26; now, as the months began with the first observation of the Moon, the 26th of the month must be within a day or two of new moon; this decidedly increases the probability that the recorded solar darkening arose from an eclipse.

Both Professor Newcomb and Mr. Nevill have rejected the suggested explanation of the apparent acceleration of the Sun as arising from a diminution of the Earth's rate of rotation. The point, however, is such a simple one that it seems worth while to restate it in other words, in the hope that they may more definitely indicate their reasons for dissenting from it.

(1) A slowing of the Earth's rotation from tidal friction necessarily involves an increase in the Moon's distance, in order that the moment of momentum of the Earth-Moon system may be conserved.

(2) A rough calculation was given showing that the lengthening of the Moon's period arising from this may be nearly as great as the apparent shortening due to the increase in the length of the day.

(3) In the case of the Sun's period, the shortening due to the latter cause would act unimpeded, so that an apparent acceleration of the Sun comparable with that of the Moon would result.

Note on the Permanency of some Photo-visual Lenses.

By William J. S. Lockyer, M.A., Ph.D. (Plates 1, 2, 3.)

The Solar Physics Observatory at South Kensington is in possession of numerous photo-visual lenses which are employed in several instruments in frequent use. All these objectives have in time developed curious markings on one or more of their internal surfaces. The object of the present note is to draw attention to, and to give a brief description of these markings.

Each of the lenses in question consists of a combination of three elements, the front and back lenses being double convex and the middle double concave. The front and middle lenses are nearly in contact, but a small air-space separates the middle from the back lens.

The material with which the lenses are made is as follows:—

The front lens is made of Schott's baryta light flint glass (O 543), the negative or middle lens is of Schott's boro-silicate flint glass (a variety of their O 164), while the third is made of a light silicate crown (Schott's O 374).

The lenses to which reference will be made vary in aperture from 3 to 12 inches, and have been left, as regards their inner surfaces, untouched in their respective instruments for periods varying from 23 to 83 months.

1907MNRAS..68...19L

Aperture in Inches.	Date of Mounting.	Date of Dismounting.	Interval in Months.	Notes on Markings.	Conditions of Situation.
12.	March 12, 1905.	Feb. 18, 1907.	23.	Very fine curly markings closely packed.	In good airy room, temperature variable.
4.	March 16, 1904.	Feb. 21, 1907.	35.	These lenses look quite clear, but on close examination it is found that there is a distinct indication of the beginning of the markings in the form of minute streaks.	In a room well heated throughout the year.
4.	March 16, 1904.	Feb. 21, 1907.	35.		
3·5.	October 1903.	Feb. 21, 1907.	40.	Beautiful feather-like markings, fairly evenly distributed, but denser near centre.	Well aired room, temperature variable.
3.	January 1900.	Dec. 14 1906.	83.	Markings all over the lens, but smaller and more closely packed towards centre.	Subjected, possibly, to vapours from arc in laboratory. Room always well warmed.
3.	January 1900.	Dec. 14, 1906.	83.	Well separated curly markings, more numerous near centre,	

1907MNRAS..68...19L

The preceding table contains a summary in convenient form indicating the intervals between the times of mounting and dismounting the objectives, the conditions of their situation, and brief notes on the markings developed.

In order, in the first instance, to indicate the appearance of the markings in question, the following four selected photographs will serve as examples. It may, however, be first mentioned how these photographs were secured.

The whole combination was first removed from the instrument in which it is employed and placed in a V-shaped wooden stand in front of a window. The camera was placed about 2 feet away from the lens and about 3 feet from the window, when the markings were carefully focussed on the ground-glass. The system of illumination of the lens under examination was as follows. The space between the lens and the camera was first covered in with black velvet. About a foot away from the lens, but on the opposite side of it to the camera, a large dull black piece of cardboard was placed near the window in nearly a vertical position to serve as a black background. The lens itself was illuminated by daylight passing through the window and falling obliquely on the back portion of the combination. Unfortunately it was found very difficult to eliminate the reflections of the window from appearing on the lens, but they are not sufficient to detract from the main object for which the photographs were taken. The photographs show, therefore, the peculiar markings on one or more of the inner surfaces of the lenses, as white on a dark background.

Fig. 1 (Plate 1) represents the 3-in. objective which has been employed in an instrument for 83 months. The markings, it will be noticed, are small, and near the middle give the lens a distinct mottled appearance. Nearer the edges their structure becomes more pronounced, and there is a greater distance between them.

Fig. 2 (Plate 1) represents the markings on another 3-in. lens which forms the camera objective of the same instrument. This lens was mounted and dismounted at exactly the same time as that shown in fig. 1 (Plate 1), and during this interval of 83 months it was situated within a foot of the other lens.

The different structure and number of the markings is very striking, and can be judged best by closely examining the photographs.

In fig. 1 (Plate 2) we have another example of quite a different appearance. This lens has an aperture of 3·5 inches, and has been in use as an objective to a small telescope for 40 months. The markings in this case are of a much finer type than those previously mentioned, and are far more elaborate in their structure.

This lens exhibits, in addition, a second set of markings, which appears on another of the interior surfaces of the combination, but which could not be photographed under the same illumination and distance, and therefore cannot be seen in fig. 1 (Plate 2). By

1907MNRAS..68...19L

reversing the combination in the V-shaped mount, refocussing the camera and varying the direction of the daylight illumination, a very successful negative was secured, a reproduction of a positive from which is seen in fig. 2 (Plate 2). Around the centre of the lens will be observed a great number of small white spots which represent the markings in question. These are quite different in form and character from any of those which have been previously described.

In the case of two 4-in. lenses a recent examination has shown that after an interval of 35 months they are just beginning to show signs of development of markings.

In this initial stage one has observed, with the help of a watchmaker's glass only, that the markings take the form of very small single streaks, more or less homogeneously scattered over the whole lens, but a little more sparse nearer the edges than about the centre.

The large 12-in. objective has developed those markings at a much greater rate. After an interval of only 23 months very fine markings, of simple structure, but fairly closely packed together, extend over the whole surface of the lens, and, as before, their structure becomes more complex as the edge of the lens is approached.

So far, no mention has been made as to the particular surface of the combination on which the markings are to be found. As a matter of fact, although it is quite simple to take to pieces any of the lenses which have been examined, it is not easy to replace them properly centred in their cells. For this reason, therefore, only one of the above-mentioned lenses has been thoroughly examined by separating the component lenses forming the combination. The particular objective thus treated was that of 3·5 inches aperture, and it exhibited both kinds of markings to a very great degree.

When markings were first noticed to develop on one of the inside surfaces of the combination it was thought that they might be due to the possible lack of permanency of the boro-silicate flint glass, since there seemed more doubt connected with the permanency of this material* than with those used for the other lenses. It was therefore found, with some surprise, that when the 3·5-in. objective was taken to pieces, both surfaces of the negative lens were perfectly clean and unmarked, and therefore not deteriorated in any respect. This result was highly satisfactory from the point of view of the lasting power of the boro-silicate flint glass, and showed that, as mounted between the two other lenses, 40 months' use had not affected it. It was the inner surface of the back lens, of light silicate crown glass, which was affected to the greatest extent, and on which the markings illustrated in the above figures were scattered. This surface, it will be remembered, is separated from the back surface of the negative lens by a small air-space. It may be mentioned that no balsam or like

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* Especially where sulphuretted hydrogen or sulphuric acid abounds, as in a town atmosphere.

1907MNRAS..68...19L

material is employed in this combination to cement the lenses together, but the surfaces are kept separate by thin washers.

In order to investigate more thoroughly the nature of the two different kinds of markings, namely, those which appeared on the inner surfaces of the back and front lenses of the 3·5-in. objective, the combination was taken to pieces and the markings microscopically examined.

This inquiry was facilitated by the kindness of Professor J. B. Farmer, D.Sc., F.R.S., of the Royal College of Science, who not only allowed me to use one of his microscopes in his own room, but also examined the markings with me. It was at once obvious that we were not here dealing with any form of vegetable growth, as seemed at first probable by the general appearance of the markings, but that both kinds were of a crystalline nature.

In the case of the back lens the crystallisation seemed to have taken place on the surface of the lens, and had the appearance of a deposit on the surface. Each fungus-like figure seemed to have originated from a small area, not a single point, and developed radially in numerous directions, throwing out ramifications as the growth from this area progressed. Under the microscope it was found that the markings were really crystals, forming at first about the small area, and then gradually growing outwards, crystal by crystal, until they formed chains of crystals, giving the fungus-like growth described above. There seemed little doubt that if this process were allowed to continue, the individual groups of crystals would all eventually unite, and seriously interfere with the transparency of the combination. In the lens under examination several of these groups have already become interlaced and instances of this can be seen in the centre portion of the lens illustrated in fig. 1 (Plate 2).

In the case of the markings on the back surface of the front lens, the form of crystallisation is quite different. Here, under the microscope, the markings (seen in fig. 2, Plate 2, as white dots scattered about the centre of the lens) are composed each of a little irregular group of crystals, formed one above the other, and projecting from the surface of the lens, not embedded in it. There is little appearance of lateral growth to the extent described in the case of the markings on the back lens. Scattered over the surface of this lens are also small single crystals, which suggest the first stage in the building up of these heaps. In this case also it is probable that if this process of crystallisation were allowed to continue, more single crystals would be formed, the single ones already existing would each develop into a small pile of crystals, and the lens would gradually become less transparent.

By the kindness of Mr. W. H. Merrett, A.R.S.M., the Instructor in Assaying in the Royal College of Science, I was permitted the use of the photomicroscope set up in the metallurgical laboratory of that institution. With the help of this instrument and with his assistance I was able to take large scale photographs of the

1907MNRAS..68...19L

crystalline formations on each of the two lenses, and some of these are reproduced on Plate 3.

Figs. 1, 2, 3 show three of the individual small groups of crystals formed on the back surface of the front lens, to which reference has just been made. The magnification employed for these photographs was 700. It will be seen that the formation is quite irregular, and, as a rule, there does not seem to be a point of origin, as if their existence was due in the first instance to the presence of a speck of dust. On the surface of this lens there appear also single crystals which are totally different from those just described. They do not show the lateral growth, as is here illustrated in figs. 1, 2, 3, but they are very much more raised from the surface on which they are formed.

The markings on the inner surface of the back lens of the combination are illustrated in figs. 4, 5, and 6 of Plate 3. Fig. 4 gives a general idea of the middle portion of one of the groups under a magnification of 45 diameters. It will be noticed that there does not seem to be a distinct single point of origin, but that the group seems to spring from a small area. An interesting point to which attention may be called is the fact that none of the lines of crystals cross each other: this can be observed in several instances in fig. 4 (Plate 3) where these lines approach each other. Further, the extremity of each line, where the crystallisation can proceed unhindered, is nearly always capped by a complete crystal.

Fig. 5 (Plate 3) is a more highly magnified (150 diameters) portion of fig. 4, and for identification purposes similar portions in figs. 4 and 5 have been lettered A, B, C. In this figure the building up of the lines by successive deposits of crystals can be more clearly seen.

Fig. 6 (Plate 3) is a portion of another group altogether. The magnification here is 700 diameters. It shows perhaps more clearly not only the individual crystals which help to build up the lines which compose the groupings previously mentioned, but the complete form of the last crystal deposited at their extremities.

Attention may here be drawn to the mottled appearance which can be seen in fig. 4 (Plate 3) in those parts of the lens where the crystals have not been formed. These markings, or "globules," as they are termed, evidently represent the stage previous to the actual crystal formation, and must have covered the whole surface of the lens before the crystals themselves were developed. As crystallisation set in they disappeared in the neighbourhood of each crystal, as if the crystals themselves required this material for their formation. The existence and behaviour of these globules are well known in crystallography, as I have since been informed by Professor J. W. Judd, of the Royal College of Science, South Kensington The whole phenomenon is clearly described and illustrated by Professor O. Lehmann in his magnificent work entitled *Flüssige Kristalle* (Wilhelm Engelmann, Leipsig, 1904). In this connection Professor Lehmann writes (p. 112), "Das die Globuliten in der Nähe von

1907MNRAS..68...19L

Kristallen verschwinden, so dass um diese ein Hof ensteht, erklärt sich vor allen dadurch, dass überkühlte Schmelzen leichter löslich sind als die kristallinisch erstarrte Substanz, in einzelnen Fällen auch durch Strömungen, welche teils durch Dichte-Differenzen, teils, speziell bei Präparaten ohne Deckglas, durch die Oberflächenspannung veranlasst werden."

Although the microphotographs reproduced with this paper indicate in a general way the structure and crystalline nature of the markings, some difficulty was met with in attempting to secure satisfactory photographs with high powers, that is, with magnifications of 150 diameters or more.

The *thickness* of the crystals and their deposition on a *curved surface* rendered it impossible to focus the objects in their entirety in a satisfactory manner, so that one had to be contented with the somewhat blurred images when these magnifications were employed.

In order to test whether the markings on the two surfaces of the objective were responsible for any absorption of light passing through the combination, the objective was set up on the V-stand mentioned previously and photographed. On this occasion the background used was white instead of black, and light was only allowed to enter the lens by reflections from this surface. If the markings absorbed light, it was expected that the resulting photograph should give one the picture of the lens with the markings dark instead of light, as was shown in the previous illustrations (Plates 1 and 2). This is exactly what occurred, and both sets of markings were faithfully recorded. Those on the back lens, which covered the larger area, were not, fortunately however, so opaque as those on the front lens, but still a considerable absorption of light was indicated, a quantity quite sufficient to detract from the efficiency of the combination.

Inquiry was next made into the probable causes of the deposition of the crystals. The weathering of glass surfaces, on account of the dust, water-vapour, etc. in our atmosphere, has received considerable attention in Germany, and quite a mass of literature now exists on the subject. A very convenient summary of such investigations will be found in Dr. H. Hovestadt's book on *Jena glass, and its scientific and industrial applications*, an English edition of which appeared in 1902 (Macmillan & Co.).

In chapter x. of this volume the chemical behaviour of glass surfaces is dealt with, and attention is chiefly confined to glasses which are most closely related to the work of the Jena glass-making laboratory. Since the photo-visual lenses here discussed are made from material supplied from Jena, the information given is therefore specially serviceable on the present occasion. There seems little doubt that it is chiefly the moisture in the atmosphere, and not dust particles, which is responsible for the actions which occur on the surfaces of the lenses here described, for the surfaces attacked are all inside, and although protected to a great extent from dust, they are still liable possibly to action by water-vapour.

1907MNRAS..68...19L

It has been shown that the durability of glass depends chiefly on its power of resisting attack by water. Glass being hygroscopic, absorbs moisture to a varying degree, and this moisture enters into chemical combination with its surface. As a result of this absorption, the alkaline components of the glass are gradually set free, and an opportunity is at once afforded for the carbonic acid of the air to combine with the alkalies and form carbonates, which are deposited in the form of crystals.

Dr. E. Zschimmer* made in 1901 an analysis of about 200 pieces of glass with polished plane surfaces, which had been stored, with a view of subsequent testing, in a dry place in Jena for several years, but so protected that they were only imperfectly excluded from air. He found that the behaviour of silicates without lead depended almost entirely on the amount of alkali contained in them. If the amount was as small as 10 per cent., dust particles initiated a deposit which he termed "dusty disintegration"; over 10 per cent., a "homogeneous decomposition" set in which attacked the glass uniformly. When the amount of alkali reached 20 per cent. the deposit became visible to the naked eye, and the greater the proportion of alkali, the coarser the phenomena, *i.e.* the formation of drops and the crystallisation of carbonates. The action of deliquescent carbonate of potash is to cover the surface with more or less minute drops, while carbonate of soda, being only slightly hygroscopic, covers it with assemblages of crystals.

In the case of the lenses dealt with in this paper, the formation of the single crystals took place on the baryta light flint glass, while the assemblages of crystals occurred on the light silicate crown.

In order to find out the actual composition of the latter glass, Messrs. Schott and Genossen of Jena were communicated with, and asked whether they would be good enough to supply this information. Needless to say, the requisite data were soon forthcoming, and I should like to take this opportunity of expressing to them my best thanks for so willingly sending me the facts desired. The following is an abstract of their reply, dated 12th April 1907, which they have kindly allowed me to publish:—

"We beg to say that the glass in question of our type O 374 constitutes a crown glass holding a high percentage of alkali, we had made at some previous time, of a similar composition as French glass. Owing, however, to its being wanting in permanency, we discontinued later on the manufacture, and hence this glass does not appear on our present catalogue.

"Its chemical composition is the following:—

B_2O_3 3%, K_2O 17%, Na_2O 5%, CaO 3·8%, PbO 1%,
As_2O_3 0·4%, SiO_2 69·8%."

With these facts before us, one is led to conclude that the

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* *Chemiker Zeitung*, 1901, 25, No. 69.

1907MNRAS..68...19L

excess of the alkali has acted in the way suggested by Dr. Zschimmer, and produced the assemblages of crystals described above.

It may be here remarked that these assemblages of crystals are very similar in growth to those formed by the crystallisation of potassium permanganate, as described and illustrated by Professor Lehmann on page 124 of the volume on *Flüssige Kristalle* to which reference has previously been made.

In order to try and reproduce the forms of crystallisation deposited on the lenses, a series of experiments was made with partial success.

As potassium (17%) was the chief ingredient next to silicon (69·8%) in the composition of the glass, solutions of pure potash with distilled water were made and poured on to the cleaned surfaces of several cover-glass lantern plates, and then drained off. The moistened sides were then covered with another cover-glass, but separated by means of small wooden diaphragms in order to allow a slight circulation of air. The glasses were kept in an upright position in a cupboard, which was frequently opened.

In a similar way, several other glasses with solutions of potash and caustic soda, mixed in the proportion of 3 to 1, were also prepared and treated in the same way.

After 10 or 15 days crystallisation in most cases began to set in, and the plates were examined and occasionally photographed.

It was most interesting to observe, not only the different forms of crystallisation on the various plates, but also the different forms on the same plate.

In the few attempts made, the form of crystallisation shown in Plate 2, fig. 1, was not exactly reproduced, although in some instances a close approximation was reached.

In conclusion, it may be remarked that the deposit of crystals on the several lenses to which reference has here been made has in no instance been removed at the observatory. The objectives were always sent away to be cleaned, and the method of getting rid of the deposit was to rub the surfaces with material soaked in dilute sulphuric acid. It is, however, satisfactory to know that Messrs. Schott and Genossen no longer manufacture the particular kind of glass which has caused this trouble, and have erased it from their catalogues. The more recently made photo-visual lenses should not, therefore, in future be hampered with this defect.

Before submitting this paper to the Society, I sent it to Mr. H. Dennis Taylor, whose investigations on the theory and practice of photo-visual lenses are so well known. He has kindly written an "Addendum," which is here attached, and which will be found a valuable contribution to the subject of the present paper.

1907MNRAS..68...19L

Addendum by H. Dennis Taylor.

Notes on Dr. Wm. Lockyer's paper on the Permanency of some Photo-visual Lenses.

Dr. Lockyer kindly submitted to me his paper before publication, with a view to my adding any remarks of my own on this interesting question.

In the first place, I would like to point out that the dates of mounting the instrument given by Dr. Lockyer are not the dates on which the objectives were put together, so that, correctly, at least 12 months should be added to the periods given, on the average.

Dr. Lockyer says that he had not been able to notice any deterioration of the optical performance of any of these objectives after being cleaned up, but that no special tests were employed.

But after cleaning at Messrs. T. Cooke & Sons' works, the objectives were carefully examined and tested for optical deterioration and none whatever was noticed. One would have thought that the crystallising out of some of the alkaline constituents of the glass would have left a network of channels in the glass surfaces, and for the presence of such small inequalities, tests by reflected light should be more appropriate, but we could not see anything. Of course, it is quite possible that the repetition over many years of such crystallisation, supposing it does repeat itself, might deteriorate the surfaces of the lenses sufficiently to cause optical mischief, but so far it has not been apparent.

With regard to the small bundles of glistening crystals forming upon the inner surface of the front lens of baryta light flint, and shown in fig. 2, Plate 2, and figs. 1, 2, and 3, Plate 3, I would like to observe that these never seem to be at all fast to the surfaces, and can always either be blown off or brushed off with a delicate camel-hair brush; and after so brushing them off, the surfaces are just as clean as before, excepting for a little dust that may have found its way in.

As regards the much more noticeable crystallisation on the inner surface of the back lens, I have never had any difficulty in rubbing it off with a soft rag dipped in very weak sulphuric acid, which, after thorough washing off, leaves the surface just like new. The amount of this crystallisation is largely dependent on the dampness or dryness of the situation in which the objective is used, and it would most probably never form at all could we keep the objective always in a dry atmosphere. Moreover, it depends also upon the particular type of crown glass used. I must here point out that the crown glass with a larger amount of alkali than usual, referred to by Dr. Lockyer as O 374, was employed in the 12-in. aperture, 3½ aperture, and one of the two 3-in. aperture O. G.'s, while the other two, of 4-in. aperture, were made out of a borosilicate crown glass, type O 599, of Messrs. Schott's catalogue,

1907MNRAS..68...19L

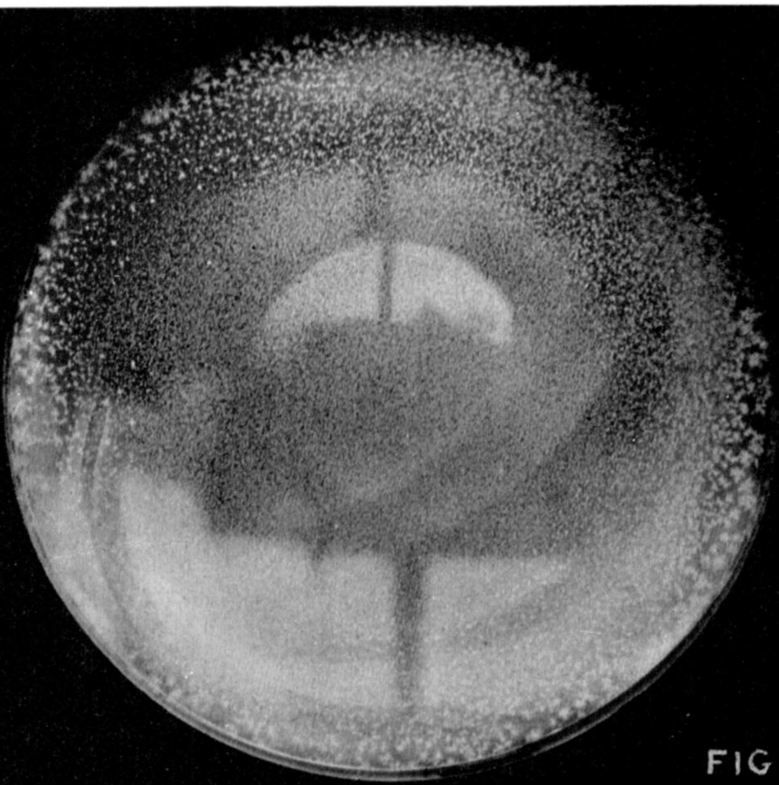

FIG. 1.

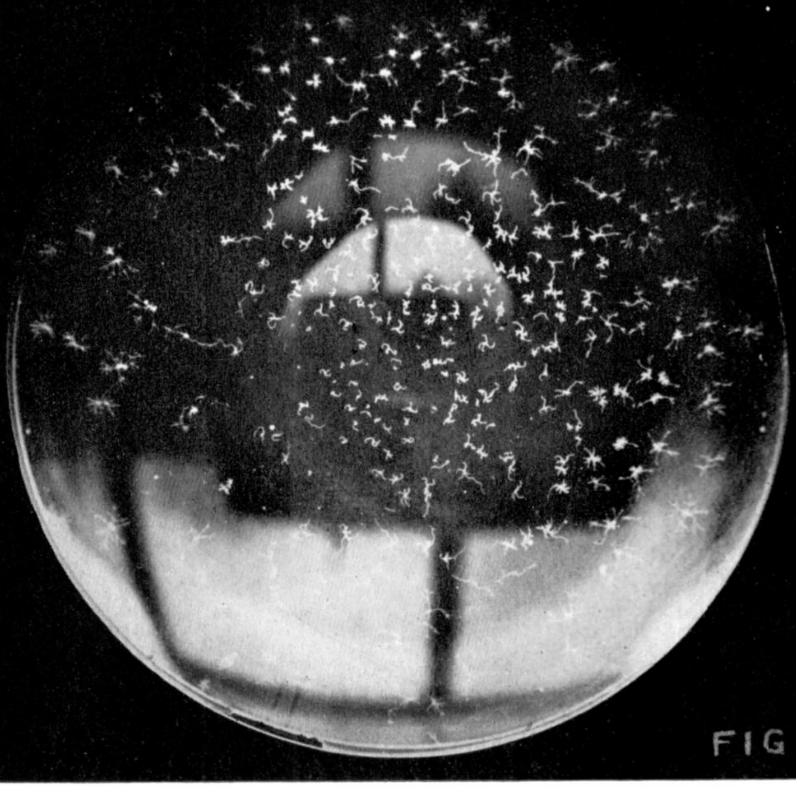

FIG 2.

[*To face page* 29.

1907MNRAS..68...19L

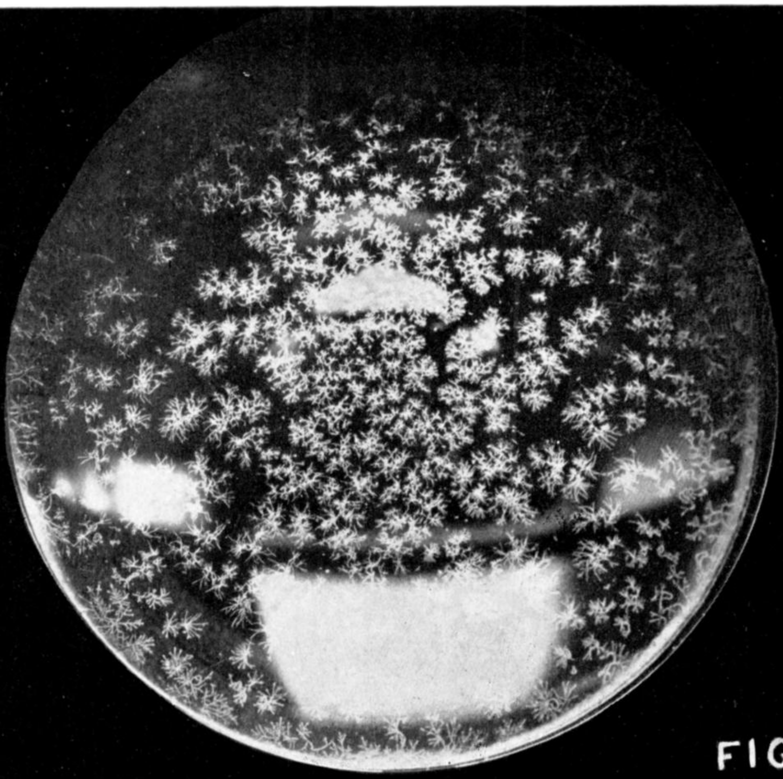

FIG. 1.

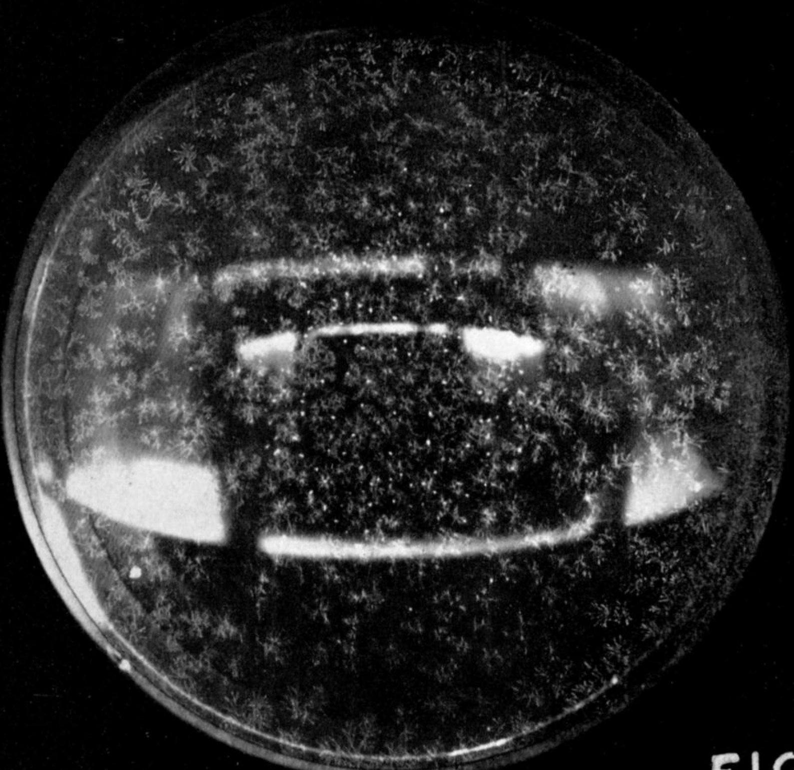

FIG. 2.

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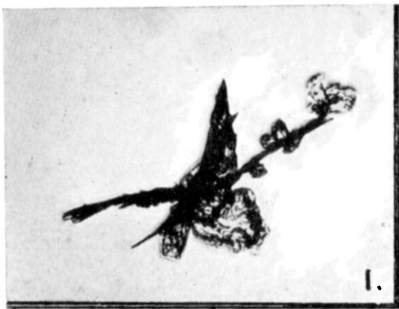
1907MNRAS..68...19L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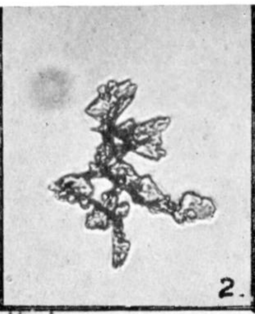
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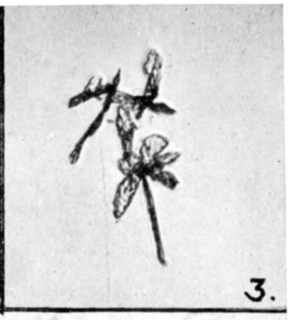
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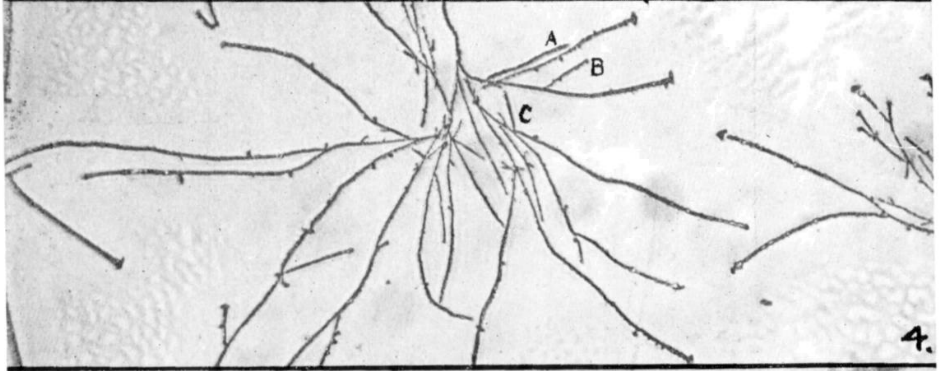

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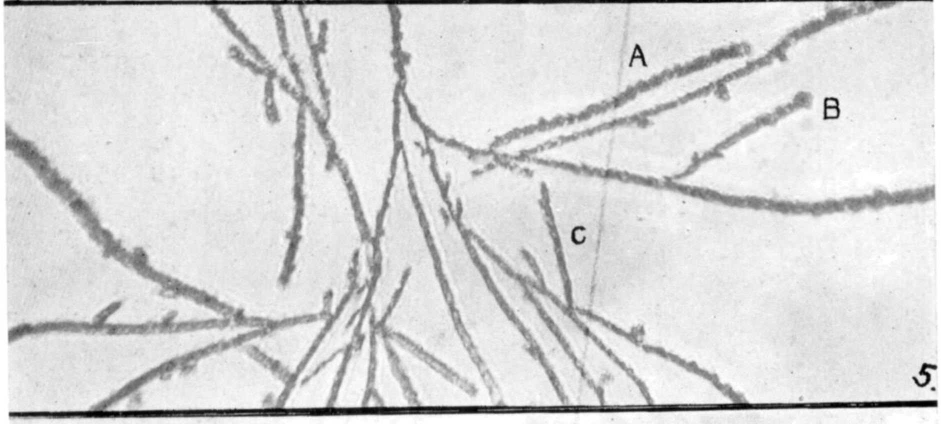

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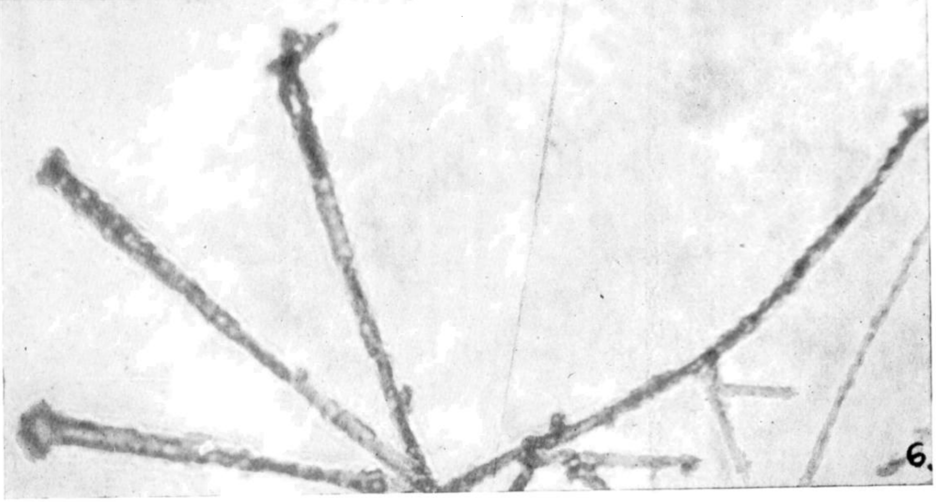
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1907MNRAS..68...19L

which latter glass is no more likely to develop hygroscopic crystallisation than is the ordinary crown glass used for older type double objective.

We have occasionally had cases, however, where ordinary double objectives that have been used in damp climates have developed the same crystallisation on the interior surface of the crown lens.

Indeed, in damp tropical climates such as that of Calcutta the crystallisation which so frequently develops on the interior surfaces of ordinary crown glass lenses is found, if left too long a time without wiping off, to leave an actual corrosion of the surface in the form of a fine grey veil. The appearance is just like that shown by an imperfectly polished surface, in which the fine pittings caused by the last emeries still survive.

Messrs. Cooke & Sons do not now employ the crown glass O 374, as it wants cleaning more often than is desirable, and use the boro-silicate crown of type O 599, or else a variety of it recently recommended by Messrs. Schott. As regards freedom from secondary spectrum, it is difficult to detect any difference between objectives made of these two different crown glasses.

DESCRIPTION OF PLATES.

Plate 1.

Figs. 1 and 2. Photographs of two 3-in. lenses after 83 months' use in a laboratory spectroscope. Fig. 1, collimating lens; fig. 2, camera lens.

Plate 2.

Fig. 1. Photograph of 3·5-in. lens after 40 months' use as a finder to a 3-ft. reflector.

Fig. 2 is a reproduction of a photograph of the same lens, but taken so as to show the markings (white dots near centre) on another surface of the combination.

Plate 3.

Figs. 1, 2, and 3. Enlarged views (700 diameters) of some of the white markings illustrated in Plate 2, fig. 2.

Figs. 4, 5, and 6. Enlarged views (45, 150, 700 diameters respectively) of parts of one of the groups of crystals shown on Plate 2, fig. 1.